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## THE LIME-SOFTENING OF WATER AND THE USE OF THE SLUDGES AS AN AID THERETO<sup>1</sup>

BY W. A. SPERRY

To soften water with lime is beautifully simple in theory but in practice there are difficulties that are both vexing and perplexing. Given ample control of the temperature and time element and a stable water of maximum softness results, otherwise the problems growing out of the tendency to form after-deposits may be of considerable moment.

Chemically, bicarbonates of calcium and magnesium are completely precipitated by the addition of lime water, the difficulties in the way of a complete realization of the lime water reaction being:

a. The fact that approximately 30 p.p.m. of the calcium carbonate produced are soluble, varying somewhat with the temperature and pressure conditions.

b. Whereas calcium is precipitated as a crystalloid, the crystal formation taking place slowly, magnesium is precipitated as a colloid. For complete removal it must be taken through the carbonate to the hydrate state, the reaction proceeding at a faster rate than does the calcium reaction.

c. Contrary to the general rule, calcium salts are more soluble in cold water than in warm, the completeness of reaction being greatly accelerated or seriously retarded by increase or decrease of temperature, as in changes from summer to winter conditions, with a corresponding change in the time element necessary.

These considerations form the fundamental elements on which the problem of design rests, the transgression of which may lead to serious difficulties.

For the municipal water softening plant this problem is more serious than it is for the smaller proprietary plant, in that the greater investment necessary in the municipal plant to insure the required "time of retention" element, as expressed in more land and larger plant, much increases the initial costs.

<sup>1</sup> Read before the Illinois Section, March 25, 1919.

The ideal condition for a lime softening plant is expressed in some form of the hot water softening system when designed with an ample time element. For the municipal plant this feature of using hot water is impossible of attainment and the design must be based upon the time required for the reactions to reasonably complete themselves under the winter condition. This involves for the mixing chambers, marked agitation and sufficient time for contact between the lime and the water under treatment before release to the settling basins, and for the settling basins, ample time for the completion of the reactions or the "curing" of the water before release to the filters or city mains.

The Grand Rapids mixing tank is a chamber built in two parts and arranged to be operated singly or in series. The smaller part provides for a retention period of twenty-two minutes at a 20,000,000 gallon rate and the larger part provides for a retention period of forty-five minutes at a 20,000,000 gallon rate. The smaller chamber is baffled so as to provide for four passes of the water in it, each pass 150 feet long, and the larger chamber provides for 49 passes, each 44 feet long—the baffles being in each case of the round-the-end or horizontal type. The larger chamber is so arranged that the water may be drawn off from it to the settling basins at either of the quarter-way intervals.

Table 1 gives results of experience at Grand Rapids with the changing seasons and illustrates the relations of time and temperature under discussion. With the river water running 220 p.p.m. total alkalinity and a magnesium content of 20 p.p.m. the temperature of the water ranging around 32° to 45°F., the alkalinity results from various parts of the mixing chamber given in table 1 are typical.

Here the significant thing is that under summer conditions with the temperature of the water ranging up around 70° to 80°F., the results attained after seventy minutes would be attained at the twenty-three to twenty-nine minute point with the alum dosage ranging 1 grain per gallon less and with greater rates of pumpage.

The essential feature of chemical application that seems to have crystalized into definite practice for lime softening at Grand Rapids is, that the lime should be added at the earliest possible moment to the water under treatment:

- a. To insure, as far as possible, complete precipitation of calcium as carbonate.

b. To maintain sufficient caustic alkalinity or excess of lime so that there may be 5 to 10 p.p.m. remaining in the water at the point of discharge into the settling basins that the magnesium may be carried through the more soluble carbonate state to the less soluble, colloidal, hydrate state.

c. To delay the application of the coagulant as late as possible to the mixing chamber and still be assured of its thorough mixing with the water, before discharge to the settling basins, the alum playing a part not so much, chemically, to reduce alkalinity, as physically to scour out and precipitate colloidal matter.

As the result of the accordion-like use of the plant in the increase and decrease of the mixing chamber length, in the increase and decrease of the amount of alum used, and in the careful maintenance

TABLE 1  
*Alkalinity after different periods of detention in the mixing chamber*  
(parts per million)

	TOTAL ALKALIN- ITY	PH. ALKALIN- ITY	CAUSTIC ALKALIN- ITY	NORMAL CARBON- ATE	MAGNE- SIUM
After 23 minutes.....	101	55	9	92	15.1
After 29 minutes.....	107	61	19	88	15.8
After 38 minutes.....	97	58	19	78	15.8
After 48 minutes*.....	91	58	25	66	15.1
After 54 minutes.....	59	31	3	56	11.8
After 70 minutes.....	59	32	5	54	10.9

\*Alum applied here at the rate of 1.5 grains per gallon.

of residual caustic alkalinity, in an effort to cope with changing seasonal conditions to produce a water of uniform qualities and maximum stability, table 2 is presented, being a study by months of the results attained for the year 1917.

Note that the decrease in temperature with consequent retardation of the lime reactions is compensated for by increases in the time of contact and increase in the alum dose applied with maintenance of caustic alkalinity.

The application of this water to the filters and city mains has resulted, through a somewhat insufficient period for curing or maturing in the settling basins, in a very moderate amount of after-reaction trouble which has:

a. Much incrusted the filter sands, though the extent to which this has occurred lessens, by that much, trouble in the distribution system.

b. Limed up about 10 to 11 per cent of the 22,000 meters in service per year, Grand Rapids being some 98 per cent metered.

c Coated the service mains to a thickness of  $1\frac{1}{8}$  to  $3\frac{3}{4}$  inch in the last six years and caused some trouble, thereby, in the opening of valves and gates.

TABLE 2  
*Results, in parts per million, of lime softening during 1917*

MONTH	RIVER WATER		NORMAL CARBON- ATE, SETTLED WATER	NORMAL CARBON- ATE, CITY WATER	CAUSTIC ALKALIN- ITY, CITY WATER	MAGNESIUM RE- MOVED	ALUM USED	PROPORTION OF MIXING CHAMBER USED
	Tempera- ture °F.	Total al- kalinity						
						<i>per cent</i>	<i>grains</i>	
January.....	32	229	62	42	0	21.6	1.9	Full capacity
February.....	32	235	62	40	4	32.0	2.0	Full capacity
March.....	35	171	42	26	9	66.6	2.4	Full capacity
April.....	47	151	38	26	7	64.7	2.3	Full capacity
May.....	54	189	42	29	5	52.8	2.1	Full capacity
June.....	65	197	40	26	7	72.2	1.9	Full capacity
July.....	73	194	40	40	2	52.4	1.3	Two-thirds capacity
August.....	72	207	50	39	4	48.1	1.2	Two-sixths capacity
September....	63	198	48	38	6	48.7	0.9	Two-thirds capacity
October.....	48	205	62	40	10	34.9	1.0	Full capacity
November....	40	214	58	44	0	32.9	1.2	Full capacity
December.....	34	234	60	40	1	40.8	1.9	Full capacity
Average.....	50	202	51	39	5	46.7	1.7	

d. Given some more or less persistent trouble with hot water heating apparatus, gas heaters, furnace coils and the like.

Tables 3 and 4 give in some detail the comparative condition of the sand and the history of the meters for the year 1917-1918.

This represents 17 per cent of the total number of meters in use, 66 per cent of which were lime-coated enough to cause their shopping, an item of considerable expense.

During the winter of 1912-1913, the first year of operation, there was a rather intensified period of trouble with the hot water heating

systems. Steam-coil-heated tanks would become furred 3 to 4 inches thick in a week's time. Instantaneous gas heater coils would become completely choked up, as would the furnace coils, the latter burning out. The author is convinced, however, that much of this trouble could have been avoided by more ample pipe sizes and by the elimination of many unnecessary ells, turns and other reductions,

TABLE 3  
*Condition of the sand, 1912-1913 and 1918*

	SAND AS PLACED, 1912	SAND AS FOUND AUGUST, 1918
Effective size, millimeter.....	0.27	Above 1.05
Uniformity coefficient.....	1.61	1±
Acid soluble, per cent.....	6.5	84.7
Approximate thickness of coating, millimeter..	None	0.255
Specific gravity.....	2.651	2.173
Volume increase, volumes.....	1	{ 1 sand, 6.5 coatings

TABLE 4  
*Nature of trouble with 3827 meters sent to the shops in the fiscal year 1917-1918*

	PER CENT	NUMBER
No information.....	4.9	189
Meters all right.....	0.1	3
Out for test.....	0.2	7
Sand clogged.....	1.5	57
Frozen.....	8.1	310
Mechanical trouble.....	19.3	738
Lime and mechanical trouble.....	12.1	461
Limed-up only.....	53.9	2062
	100	3827

all of which seemed favored places of deposit for the lime coatings. This trouble was the more aggravating in that it occurred at such a time as to make concurrent the most difficult water to treat with the greatest demands for hot-water heating.

Laboratory tests seemed to identify this with the percentage of magnesium removed, such that when the removal effected was 25 per cent or more the trouble from this source was reduced ma-

terially. Operation in the succeeding years, therefore, became controlled by the percentage of magnesium removed, in that with magnesium removed to the extent of 33 to 46 per cent troubles due to after-deposits were apparently diminished and complaints arising from trouble with hot-water heating apparatus decreased.

Within the last year continued efforts to cope with the small, but persistent, troubles arising from after-deposits, coupled with reasons of an economic nature arising out of the increasing cost of alum, have lead to a change in the author's ideas as to the exact rôle played by the magnesium in lessening such troubles. Formerly, he believed the troubles due almost entirely to colloidal magnesium and bent all efforts towards its removal, through increases of the amount of alum used and the rigid maintenance of residual caustic alkalinity. The fact that magnesium was not a predominating characteristic in the coatings deposited, there being but 8 to 15 per cent therein, did not seem to square with the theory, even though it was a pronounced fact that removal of magnesium was consistent with reduced after-reaction troubles. The author is beginning to suspect that, in reality, the major cause of the more stable effluent lay in a reduced normal carbonate content of the water going to the city mains. While it was true that increase of alum and maintenance of caustic alkalinity increased the amount of magnesium removed proportionately, it also not only reduced the normal carbonate content of the water, but, in addition, maintenance of caustic alkalinity tended to prevent deposit, to some extent, of that portion of normal carbonate that may have been present in a supersaturated state. Table 5 throws light on this.

In 1912-1913 occurred the worst period of after-deposit troubles. For that year the magnesium removal was but 25 per cent and the normal carbonate alkalinity of the city water for that period was greater than for the average of the succeeding years by 51 per cent, being 65 p.p.m. as against an average of 43 p.p.m. for the five succeeding years.

This explains the general nature of the problem that was confronting the author, a solution for which was sought in the experiments discussed in this paper. There was a constant seeking for some method of operation that would compensate for the rather insufficient settling basins for lime softening operations, so that the city would save all the desirable and economic features of a soft water without a continuance of the various troubles discussed and

without the expenditure of increasing amounts of alum, the cost of which was mounting.

The experiments were largely inspired by what was being done with the use of air and sludge in the treatment of sewage and the possible feasibility of pumping back, in like manner, the settling basin sludges into the mixing chamber to intensify the removal of colloids, to save alum if possible, and at the same time to so accelerate the curing of the water as to stabilize the effluent to a point of possibly eliminating entirely the after-reaction troubles and their attendant annoyance to the hot-water user, the expense of cleaning limed meters, and the elimination of sticking gates and valves.

The sludge, in question, is a mixture of some 85 per cent calcium carbonate, 4 per cent magnesium hydrate, aluminum hydrate, mud,

TABLE 5  
*Average amount of alum applied and removal of magnesium*

YEAR	NORMAL CARBONATE, CITY MAINS	CAUSTIC ALKALINITY WATER CITY MAINS	MAGNESIUM REMOVED	ALUM APPLIED
	<i>p. p. m.</i>	<i>p. p. m.</i>	<i>per cent</i>	<i>grains</i>
1913	65	1	25.0	1.0
1914	44	5	33.6	0.7
1915	48	3	37.6	0.9
1916	43	3	43.7	1.2
1917	39	5	46.7	1.7
1918 to August 1	41	6	42.2	1.2

organic matter, etc., and is produced in enormous amounts. It covers the settling basins, which are approximately 110 feet by 210 feet by 12 to 15 feet deep, with a layer of sludge from 1 to 10 feet deep, with one-third to one-half the area covered to a depth of 8 to 10 feet deep, every one and one-half to two months and aggregates 6000 to 7000 tons a year, based upon an average pumpage of 12,200,000 gallons per day and a reduction of the raw water in total hardness, through the use of lime, of from 225 p.p.m. to 95 p.p.m., for the water passing to the city mains, as the average for 6 years, a reduction of 60 per cent.

Preliminary laboratory experiments indicated:

- a. That time of contact was not a factor beyond the time required for thorough intermixing.
- b. That the volume of sludge in contact was of exceeding importance.



c. That the sludge was most effective when applied to water from the mixing chamber taken at a point just after the alum addition, i.e., at a point where the normal lime reactions were most nearly completed.

d. It seemed most effective, therefore, not so much to hasten the chemical reactions as to remove the products of the reaction.

e. That the sludge did not seem so effective, at least in the volumes attainable by the pumps at hand, when applied to water treated under summer conditions as when applied to water treated under winter conditions.

Table 6 gives results of some of the laboratory experiments and is illustrative of points (a) and (b). The water was taken from

TABLE 6  
*Results of laboratory experiments in treating water with sludge*

SLUDGE ADDED, PER CENT BY VOLUME	TIME	TOTAL ALKALINITY	PH. ALKALINITY	CAUSTIC ALKALINITY	NORMAL CARBONATE	MAGNESIUM
	<i>minutes</i>	<i>p. p. m.</i>	<i>p. p. m.</i>	<i>p. p. m.</i>	<i>p. p. m.</i>	<i>p. p. m.</i>
0	0	61	28	0	56	16.3
5	3	32	15	0	30	13.4
5	10	29	12	0	24	12.4
10	3	27	12	0	24	11.0
15	3	23	11	0	22	9.6
20	3	20	9	0	18	9.6
25	3	19	9	0	18	8.6

near the end of the mixing chamber after the application of the alum and at a temperature of 32°-35°F.

In each case the amount of air applied was such as just to keep the sludge well up in suspension. The result of this was to form the sludge into large ragged feathery flocs as large as the end of one's little finger that fairly seemed to fall from suspension like sand.

These experiments looked so promising that during the winter of 1916-1917 arrangements were made to carry out a plant-size experiment. At the point of discharge from the mixing chamber into the settling basin a 6-inch centrifugal pump was set up, coupled to a spare 10-horsepower motor. Its suction was dropped into the settling basins at a point where the sludges accumulated to the greatest depth and connected to a line running lengthwise of one section, some 100 to 120 feet long, bored with 1-inch holes on alter-

nate sides of the horizontal diameter and spaced so as to be 1 foot apart on alternate sides of the pipe, i.e., a hole every 2 feet apart on either side. The pump was further arranged to discharge into the mixing chamber at a point some four to six passes from its place of discharge into the settling basin.

Several runs were made with this pump so arranged, the results of which proved largely confirmatory of the preliminary laboratory experiments, especially as regards its relative effectiveness in the

TABLE 7

*Results of a typical large-scale test of the effect of sludge; made in January, 1917*

TIME	WATER AT GATE K					WATER AT GATE L					SLUDGE USED, PER CENT BY VOLUME
	Total alka- linity	Ph. alka- linity	Caus- tic alka- linity	Nor- mal car- bonate	Magne- sium	Total alka- linity	Ph. alka- linity	Caus- tic alka- linity	Nor- mal car- bonate	Magne- sium	
	<i>p.p.m.</i>	<i>p.p.m.</i>	<i>p.p.m.</i>	<i>p.p.m.</i>	<i>p.p.m.</i>	<i>p.p.m.</i>	<i>p.p.m.</i>	<i>p.p.m.</i>	<i>p.p.m.</i>	<i>p.p.m.</i>	
10.00 a.m. ....	100	40	0	80	24.0	66	32	0	64	19.2	0
10.30 a.m. ....	98	38	0	76	24.0	74	32	0	64	19.2	0
11.00 a.m. ....	103	44	0	88		72	32	0	64	18.2	0
Average.....	100	41	0	81	24.0	71	32	0	64	18.8	0
11.30 a.m.*....	86	32	0	64	22.1	44	20	0	40	13.4	7
12.00 noon.....	70	30	0	60	15.3	46	20	0	40	16.3	6
12.30 p.m. ....	94	48	2	92	11.5	46	30	14	32	10.6	5
1.00 p.m. ....	136	64	0	128	23.0	64	36	8	56	11.5	3
Average.....	96	43	0	86	17.9	50	26	2	42	12.9	5
1.30 p.m.†....	108	64	20	88	19.2	88	50	12	76	16.6	0
2.00 p.m. ....	115	52	0	104	23.0	106	60	14	92	16.6	0
Average.....	111	58	10	96	21.1	97	55	13	84	16.6	0

\* Sludge pump started.

† Sludge pump stopped.

winter and summer months and as regards the importance of the volume of sludge in contact with the water under treatment. It proved disappointing in particulars noted further on. The results in table 7 are given as typical of a run made in January, 1917, where the water was followed from the mixing chamber through the settling basins into the clear wells. Note that the water at gate K is at a point one-quarter of the distance from the end of the mixing chamber (at the point found best for the application of the alum) applied on this day at the rate of 1.24 grains per gallon. The water at gate L

is at the point of discharge of the mixing chamber into the settling basins. The sludges were applied at a point midway between gates K and L. During this run, every effort was made to keep the application of the lime as steady as possible, all other factors, as rate of pumpage, being so controlled as to eliminate all variables but the effect of the applied sludge on the water under treatment, since, under the best conditions, the application of the lime is a variable factor having much to do with the efficiency of the final results obtained.

Table 8 is presented to show the average water from gate L for the two periods, without sludge and with sludge, together with the total average of the water at gate K.

TABLE 8  
*Average results with and without sludge*

GATE	PERIOD	TOTAL ALKA- LINITY	PH. ALKA- LINITY	CAUSTIC ALKA- LINITY	NORMAL CAR- BONATE	MAGNE- SIUM
		p. p. m.	p. p. m.	p. p. m.	p. p. m.	p. p. m.
K	10 a.m.-2 p.m.....	101	46	2	99	18.0
L	No sludge.....	81	41	5	76	17.9
L	5 per cent sludge.....	50	26	2	48	12.9
L	Reduction, percentage.....	38	37.6		36.6	28.0

It was one of the expectations in connection with such a treatment that with a water so reduced in alkalinity and normal carbonate content there would be a diminution of the drop in alkalinity on passing the filters, which would be strong evidence of the stable character of the water so produced and be strongly in contrast with the usual experience, as noted by comparing the normal carbonate alkalinity of the settled water with that of the filtered water as shown for the year 1917 in table 2, the average reduction of 12 p.p.m. normal carbonate alkalinity explaining entirely the rapid growth on the sand grains. Table 9, therefore, follows the water under study around to the filters before and after passing the sand where it shows but 1 p.p.m. drop as against a 13 p.p.m. drop across the sand for the unsludged water.

The plant-size experiments showed the ability of the sludge treatment to:

a. Reduce the alkalinity and normal carbonate content of the water.

TABLE 9

*Change in character of water as it passed through the plant*

TIME	SETTLED WATER, SURFACE OF FILTERS					EFFLUENT FROM FILTERS				
	Total alkalinity	Ph. alkalinity	Caus-tic alkalinity	Nor-mal car-bonate	Magne-sium	Total alkalinity	Ph. alkalinity	Caus-tic alkalinity	Nor-mal car-bonate	Magne-sium
	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.
11.00 a.m. ....	84	24	0	48		67	31	0	62	
12.00 noon .....	64	28	0	56		48	23	0	46	
12.30 p.m. ....	65	28	0	56		50	25	0	50	
1.00 p.m. ....	65	30	0	60		53	28	3	50	
*1.30 p.m. ....	47	21	0	42		45	25	5	40	
2.00 p.m. ....	40	19	0	38		42	23	4	38	
2.30 p.m. ....	35	19	3	32		36	21	6	30	
†3.00 p.m. ....	36	22	8	28	8.6	32	21	10	22	10.5
3.30 p.m. ....	42	28	14	28	11.5	34	23	12	22	5.7
4.00 p.m. ....	45	33	21	24		35	25	15	20	
4.30 p.m. ....	51	35	19	32		40	27	14	26	
5.00 p.m. ....	55	36	17	38		41	28	15	26	

\* At this point the sludge treated water came around on the filters.

† At 3 p.m. the last of the sludge treated water was passing, as can be noted by the return to normal of the alkalinities of the two waters under study, at 3.30 p.m.

TABLE 10

*Summary of results detailed in table 9*

	TOTAL ALKA-LINITY	PH. ALKA-LINITY	CAUSTIC ALKA-LINITY	NORMAL CAR-BONATE
	p. p. m.	p. p. m.	p. p. m.	p. p. m.
Average of <sup>2</sup> unsludged, settled water 11.00 to 1.00 and 4.00 to 5.00 .....	61	31	8	53
Average of filter effluents for same period.....	48	27	1	42
Loss through filters.....	13			11
Average of sludge-treated, settled water 1.30 to 3.00.....	39	20	3	36
Average of sludge-treated water after passing filters.....	39	22	6	33
Loss through filters.....	0			3

b. Reduce the magnesium content of the water for the winter months beyond that possible without it or else at the possible expenditure of an impossible amount of alum.

c. Produce, with its aid, a water whose normal carbonate alkalinity was reduced to an average of 33 p.p.m., a point 10 p.p.m. lower than that possible over an average of five years as shown in table 5.

d. Produce a water showing a negligible drop across the filters as indicated in table 10, where the drop of from 11 to 13 p.p.m. was reduced to from 0 to 3 p.p.m.

To this extent the process was encouraging, but it proved unfavorable for the following considerations:

a. Because of the difficulty of getting a constant supply of sludge in sufficient amounts. It was assumed that the sludge could be made to travel somewhat as a belt, that it could be lifted into the mixing chamber where it would do its work only to deposit rapidly again, the suctions being laid in a place thought to be most favorable for such abundant redeposit, especially in view of the fact that it was constantly being added to by the newly treated water. Actual pumping, however, soon showed an inability to supply sludge at a rate greater than 5 to 7 per cent by volume of the sludge and for a period of more than one to one and one-half hours at a time, when, in the midst of plenty, the supply would cease entirely.

Sludge could be pumped each time until there had been produced about each suction hole a more or less cleared area, after which the sludge would cease to come and the experiment for the day would have to be terminated until such time as the sludge had again been built up. The sludge absolutely refused to flow to the pump suctions and the permanent adoption of such a scheme seemed dependent on the use of some device that would either bring sludge to the suctions as through the use of a Dorr thickener or else the devising of some type of traveling or flexible suction that would follow up the sludge. Neither of these schemes seems impossible of solution.

b. Because of the production in the water of a finely divided suspended matter, both difficult and expensive to remove by the use of alum, a procedure hardly to be considered in view of the fact that the whole object of the scheme, to conserve the alum, would be defeated. The production of this finely divided suspended matter was at variance with the laboratory experiments and is

somewhat difficult to explain unless the mechanical action on the sludge as it was drawn through the many suction holes and threshed about in the pump impeller were responsible, though there is to be set against this idea the fact that water dipped from the mixing chamber just at its time of discharge showed the same large ragged flocs that were produced in the laboratory with air agitation, and the same tendency to settle rapidly. It was also impossible to get sludge runs long enough to gain an idea of just how such a water would act on the filters either to increase the loss of head rapidly, the amount washwater used, or how it would interfere with the quality of the effluents.

No agitation was used in the plant-size experiments other than that afforded by the normal baffling of the mixing chambers, this point again checking the laboratory findings of the comparative importance of the volume of the sludge used rather than the length of time in contact.

It is difficult to state with sureness any exact explanation of these phenomena. It would appear that they are largely mechanical, in that the sludge used contains no residual chemical activity, it apparently acts to scour out colloidal matter, as evidenced by the reduction of the magnesium content of the water and as further evidenced by the apparently greater efficiency to do so when applied to the water that has its lime reactions most nearly completed, and, finally, as evidenced by the fact that the reduction in the normal and total alkalinity must come about through the introduction of the many crystals of calcium carbonate that act as foci for the more rapid formation of such crystals than normally takes place.

With the establishing of these facts the work was terminated through pressure of other work and the lack of adequate technical assistance, though it is felt that the results attained give sufficient promise to warrant further work thereon. It is understood that a plant at Lawrence, Kan., inspired by these experiments has incorporated something of this idea in its design but all details as to the truth of this or type of design are lacking. Finally the idea seems particularly applicable to the smaller plants, either for the smaller communities cursed with hard well waters, or the intermittent types or the proprietary plant.

*DISCUSSION*

W. F. MONFORT: The principle of the scheme is undoubtedly sound; to prolong the period of contact or increase the area offered by the sludge as sand in the sand filters coated with calcium carbonate and mixed with magnesium compounds assists in this reaction. At Quincy, Ill., no incrustation occurred in the distribution systems but the sand had less than 25 per cent of sand and over 75 per cent of other incrusting matter.

M. F. STEIN: As regards the deposits that the author said did not contain an extensive amount of magnesium, the same thing occurred in Cleveland with plates used in testing softened water. The deposits in the case of plain iron plates were composed largely of carbonate of iron; in the case of galvanized iron, carbonate of zinc; and in the case of brass plates there was a very slight deposit, which was rather surprising owing to the trouble that is often caused with lime-softened water coating valve seats. There was also practically no deposit on glass plates, which is rather interesting from a theoretical view point, as glass is an ideal surface for contact action in colloidal phenomena. With magnesium in colloidal state, one would expect it to deposit on the glass and be coagulated by the glass through contact action.

A question suggesting itself regarding the continued use of sludge is whether the sludge will keep in a sufficiently fresh condition. At Cleveland it was found that the deposit of sludge in the settling basin, over perhaps ten days or two weeks old, would develop a very strong odor which was highly disagreeable and made necessary the cleaning of the basins. It is not known whether this was due to the lime and magnesium salts or whether it was due to the organic matter in the water.

W. A. SPERRY: One thing that interested the author at Grand Rapids at the starting of the plant was the similarity of the sludge produced to that produced at Columbus, Ohio, where lime softening is accomplished in a similar manner. When cleaning the basins the fishy odor mentioned by Mr. Stein was strongly pronounced and so similar to the odor of the Columbus sludge during cleaning there, that if one were taken blindfolded into either plant one could not tell which plant was visited. Apparently while pumping the sludge back, although there was evidence of this odor being present as the

sludge was brought to the surface, it did not transmit itself to the water in amounts sufficient to be detected.

The amount of sludge produced varies with the amount of hardness carried by the water as affected by the varying seasons, amount of rainfall, etc. During the winter, with the rivers largely fed by springs, the water increases greatly in hardness, with a corresponding increase in hardness to be removed. With the passing of the winter's snow and spring rains, there is a diluting effect, reducing the amount of softening necessary and the sludge produced as a consequence, but also greatly increasing the suspended clay, silts, sand, etc. The figures given in the paper are very good averages for the year where the sludge produced from an average dosage of 8 to 10 grains of 88 per cent lime per gallon will amount to from 16 to 20 grains per gallon settling out in the settling basins.